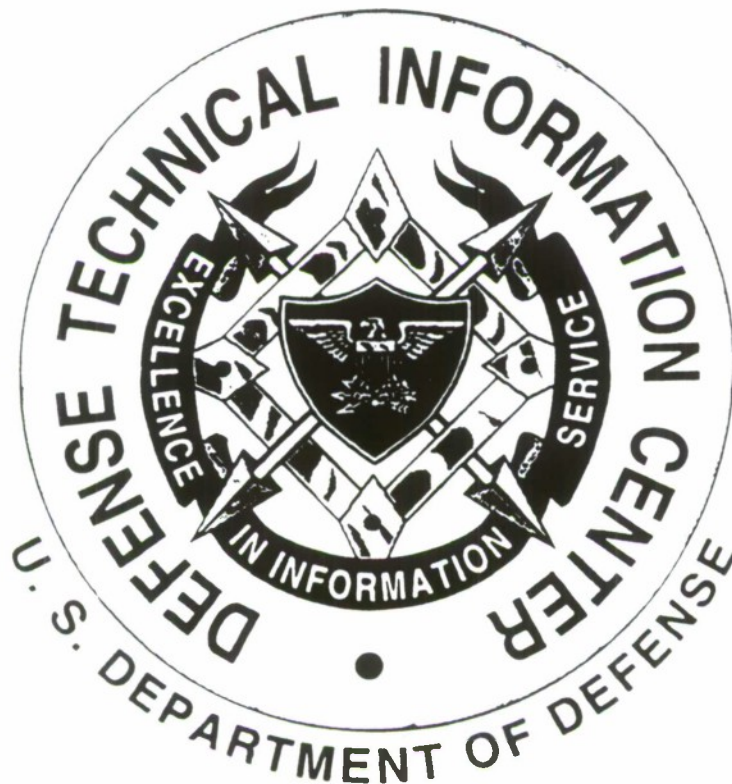


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AD-689776

PROJECT REPORT

HELICOPTER  
ENROUTE  
IFR

Project No.  
65-920-6  
(Enroute)

Prepared by:

Allan W. Hunting

Frank Parr

January, 1968

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Flight Standards Service  
National Flight Inspection Division  
Washington, D. C.

922689

PROJECT REPORT  
Project No.  
65-920-6  
(Enroute)

# HELICOPTER ENROUTE IFR

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January, 1968

Department of Transportation  
Federal Aviation Administration  
Flight Standards Service  
Washington, D. C.

### A B S T R A C T

An evaluation of Los Angeles Airways, Inc., pilots flying selected VOR routes was conducted under simulated IFR operation to assess the vertical and lateral flight technical error. Radar flight track tracings and movie film were used to collect data. A statistical analysis of the data shows that stabilized helicopters may be safely operated IFR within  $25\frac{1}{2}$  miles of a VOR station when at least 500 feet of obstruction clearance is provided in the area two nautical miles on each side of the radial providing course guidance with reduced obstruction clearance beyond 2 NM to a maximum lateral distance of 3 NM.



## C O N T E N T S

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## I N T R O D U C T I O N

The certification of air carrier helicopters and pilots for IFR intracity operation poses a number of problems relating to re-evaluation of existing procedural standards for their suitability for helicopter operations.

Integration of scheduled helicopter air carrier operations into the fixed-wing IFR environment will also burden the terminal airspace system with additional separation problems in metropolitan areas where high IFR traffic activity already exists.

The need for more flexible use of terminal airspace to accommodate discrete IFR helicopter routes and altitudes is reflected in proposed reductions of obstruction clearances and lateral airway/route widths. Whether proposed reductions are consistent with safety is in part a question of performance factors of both the helicopter and the pilot.

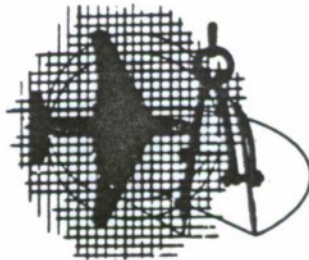
This study deals with the capability of the aircraft and the pilot to operate under reduced vertical and lateral obstruction clearance requirements in the intra-terminal environment.

### SPECIAL NOTE:

The following documents were used in identifying vertical error factors:

NACA TN 4127 "The Measurement of Pressure Altitude in Aircraft", 1957. William Gracey.

Doc 7672-AN/860-ICAO "Panel on Vertical Separation of Aircraft", First Interim Report, 1956.



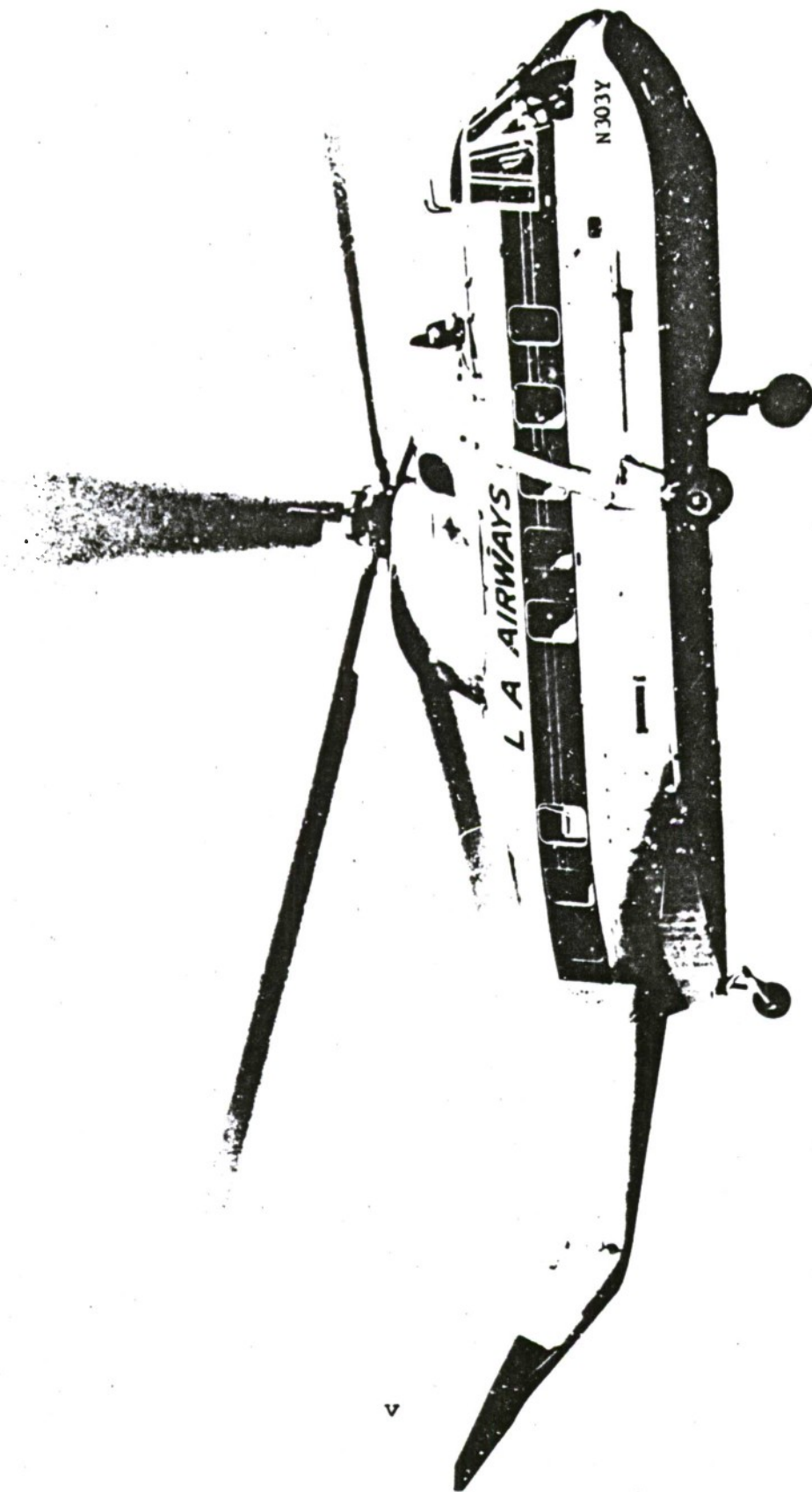


FIGURE 1. S-61-L (Sikorsky) Helicopter Aircraft.

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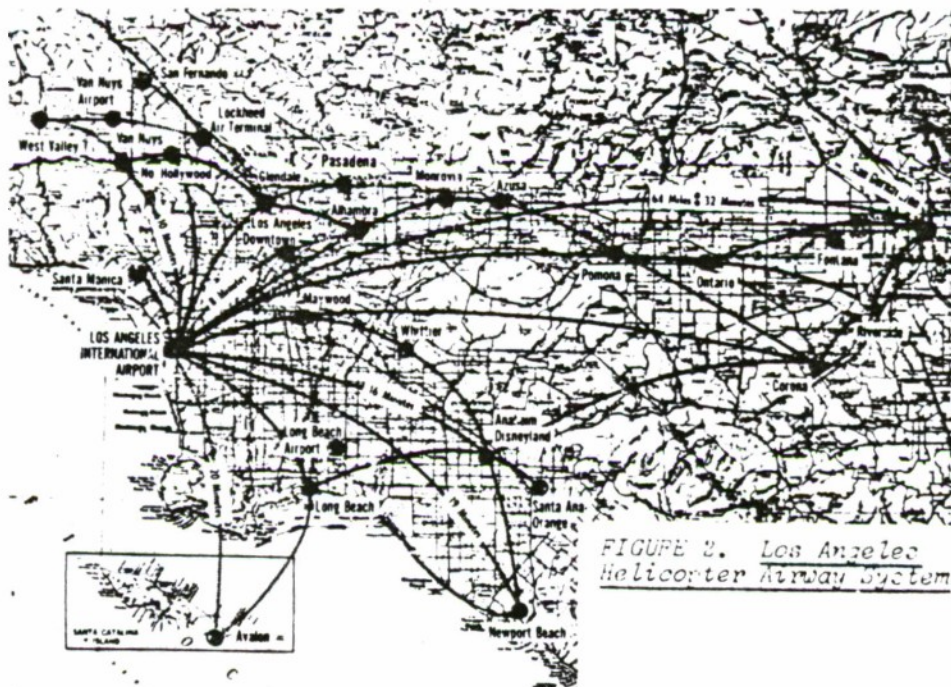
## I STATEMENT OF THE PROBLEM

Sufficient data were not available for the establishment of criteria upon which to predicate minimum obstruction clearances and airway widths for IFR operation of helicopters.

Los Angeles Airways has been certificated to operate rotary wing aircraft over specific routes.

Fixed wing criteria for airways design and obstruction clearance areas is considered to be too restrictive to be applied to rotary wing aircraft.

NOT REPRODUCIBLE



## II TEST OBJECTIVES.

- A. Determine the flight technical error, defined as the random deviations from intended flight level and intended flight track, by recording the performance of instrument qualified helicopter pilots.
- B. Calculate vertical errors by applying the method which was presented by W. Gracey in NACA TN 4127. Calculate lateral deviation probability by application of the root-sum-square method of statistical analysis to the variables of ground station, receiver, and flight technical errors.
- C. Determine the following:
  - 1. Minimum obstruction clearance required.
  - 2. Required widths of primary and secondary airway and route obstruction clearance areas.
- D. Consider whether obstruction clearance vertical values can be used to establish vertical separation between two rotary-wing aircraft routes and between rotary-wing and fixed-wing traffic.



### III. TEST METHODS

Altitude and lateral displacement data were collected in flight during normal scheduled operations conducted by Los Angeles Airways, Inc. All recorded flights were conducted under simulated IFR (hood). Routes selected were those proposed for IFR from Los Angeles International Airport to Anaheim and from Anaheim to Newport Beach. Selection of these routes imposed a minimum of interference with scheduled passenger-carrying operations, provided data collection opportunities when cockpit workload was representative for helicopter intra city operations, and permitted low altitude runs with radar monitoring.

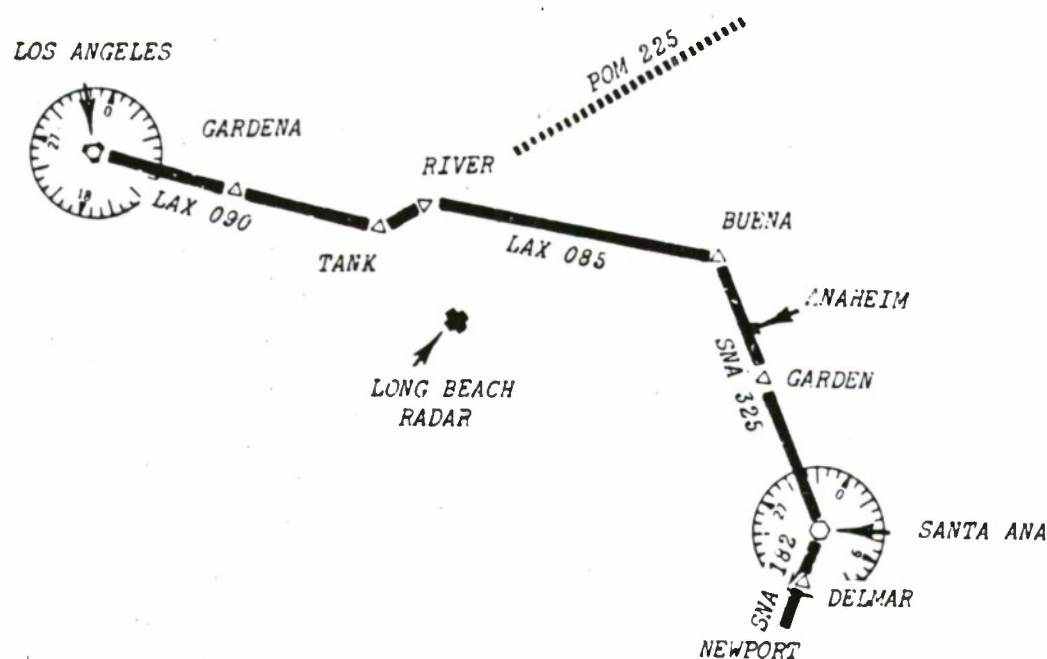


FIGURE 3. Evaluation Route.

All of the eight Los Angeles Airways pilots certificated for IFR helicopter operation participated in the tests. Two round trips were programed for each pilot. Two pilots completed only half the scheduled tests owing to regulatory limits on flight time.

The recorded weather conditions were typical of the Los Angeles area; westerly winds averaging 15 knots and smooth flying conditions with occasional light turbulence.

### VERTICAL DEVIATION

Fifty-six runs provided vertical data. Altitudes sampled were 600, 1100, 1500, and 2000 feet MSL. Air traffic, weather conditions, and noise abatement considerations dictated altitudes flown. The data collected on the 600-foot runs are included in this report.

### LATERAL DEVIATION

Thirty-eight runs provided lateral deviation data. Long Beach Radar controllers recorded aircraft flight tracks on radar scope overlays. Data collection records were maintained by the controllers.

NOTE: A "run" for test purposes was a flight between Los Angeles and Anaheim or between Anaheim and Newport Beach.



#### IV. DATA ACQUISITION

The collection of data in no way interfered with the normal operation of the aircraft, pilots' activities, or air traffic control procedures. Controllers and pilots were all briefed to conduct the simulated operations "as usual".

##### VERTICAL DEVIATION

Altitude data were collected on 8 mm movie film by remote control of a camera mounted on the bulkhead above and behind the pilot seat. The camera was triggered by the project officer seated in the passenger compartment adjacent to the closed cockpit access door. The only contact maintained between the pilots and the project observer involved signals from the third pilot indicating when the aircraft reached level flight and when descent was begun.

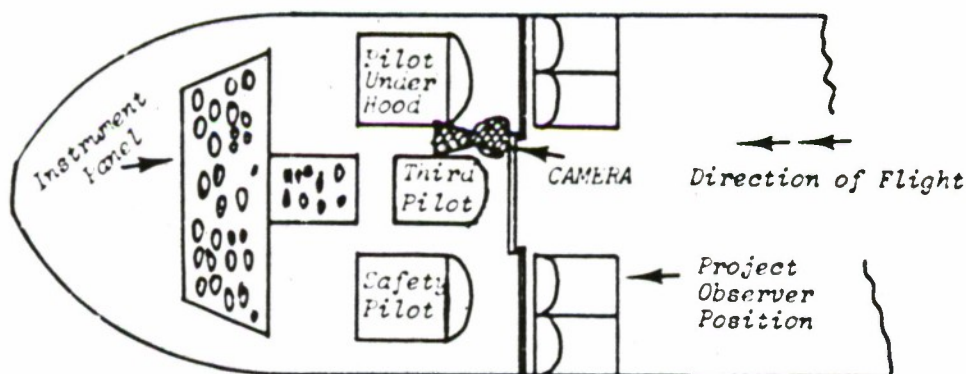


FIGURE 4. Camera Installation.

Film samplings were based on the estimated level flight time between heliports. The time was LAX-Anaheim, 12 minutes and Anaheim-Newport Beach, 6 minutes. On each 12 minute run 12 recordings of the altimeter were made, each 10

seconds long. On each 6 minute run 12 recordings were made each 5 seconds long.

Altitudes flown were those normally assigned during helicopter operation under simulated IFR conditions, except that by prearrangement with ATC the stages between Anaheim and Newport Beach were flown at 600 feet when weather and traffic conditions permitted.

#### LATERAL DEVIATION

Radar controllers in the Long Beach Approach Control facility recorded flight tracks on prepared overlays mounted on radar scopes. An airway was laid out with its primary area drawn 2 NM on each side of the route centerline and a secondary area 1 NM wide was placed on each side of the primary area. This airway served as the size-shape area over which the simulated instrument operations were conducted.

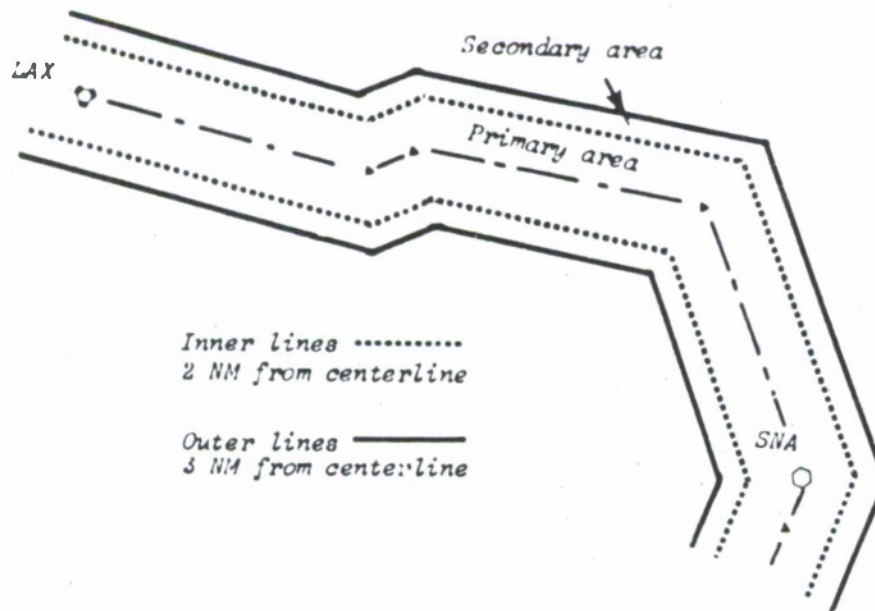


FIGURE 5. Simulated Airway.

## V. DATA ANALYSIS AND REDUCTION

### VERTICAL DEVIATION

From the photo records of flights assigned 600 feet MSL, the indicated altitudes were tabulated at intervals of 25 frames along the 8 mm movie strips. Figure 9 in the Appendix shows the tabulation and the derivation of standard deviation and statistical mean from these data. One standard deviation is 27 feet (27.2). Figure 8 in the Appendix applies this Flight Technical Error statistically with the other random errors in altimetry to compute total random altimeter error for both helicopter and fixed-wing aircraft. These random errors are then applied in Figure 6, page 11, to define total vertical error for approach and enroute operations, and for helicopter and fixed-wing separation requirements.

The errors enumerated in the data reduction do not include tubing lag error and service error. The tubing lag error can be considered negligible for the aircraft and operations involved. (Tubing lag error is induced by the tubing volume, the volume of the instruments connected by the tubing, the rate of pressure change, and the altitude). Likewise, service errors, such as leaks in the system, ice or moisture accumulation, etc., can be considered insignificant due to proper maintenance and inspection of the altimeter system.

The assignment of maximum numerical values for altimeter errors included in the data reduction is shown below. If not otherwise identified, the source of these values is the NACA Technical Note 4127.

1. Friction error is due to friction in the altimeter mechanism transmitting the diaphragm movement to the pointers, plus friction in the temperature compensating pins. The maximum error evaluated during this project was 40 feet in the Sea Level to 5000 foot altitude range. However, a value of 100 feet is assigned on the basis of NACA helicopter flight tests, where this is the approximate error found. This error factor value is based upon discussions with Mr. Jack Reeder, NASA Research, Langley AFB, Virginia.
2. Temperature error is due to the inability of the instrument, which is designed to compensate for effects of temperature over a considerable range, to eliminate all temperature effects. The maximum 10 foot value is assigned, regardless of altitude.

3. Instability is a mechanical error due to different reactions of the instrument during two consecutive climbs or descents. This error shows a non-linear variation with altitude, decreasing from 100 feet at 40,000 feet to 32 feet at 5000 feet. Since the reference document does not present error values for altitudes below 5000 feet, the instability error for the 5000 foot level is used. This value is 32 feet.
4. Coordination error is due to the inability to obtain complete correspondence between the pressure-scale graduation and the height scale of the altimeter. This error is 25 feet.
5. Balance error is due to the impossibility of coordinating the state of balance of all moving parts of the altimeter to such a degree that the instrument will be entirely independent of its position in relation to its calibration position (Kollsman Setting 29.92" Hg.). This error is a constant 20 feet at all altitudes.
6. Station barometer error is the allowable error in the instrument which is the source of the station altimeter setting. This error is 25 feet. Altitude does not vary the error.
7. Manometer error is that error in the manometer used to calibrate the altimeter. The error is 0.01" Hg., with corresponding altitude errors varying from 10 feet at sea level to 38 feet at 40,000 feet. The factor used in this project was 10 feet.
8. Precision error is induced by the deviations of the hysteresis cycle on either side of the mean curve. It is referred to as the precision of the scale error. For this test a value of 30 feet is used.
9. Flight technical error is the random deviation in altitude resulting from operation of the system. For example, errors in reading the barometric scale, errors in reading the altitude scale, and errors in determining the altimeter setting at the ground station are operational errors which when combined, result in a flight technical error. For this test the flight technical error was derived from analysis of data gathered at the 600 foot level. The value used is 82 (81.6) feet. A histogram and statistical analysis of this error is shown in Figure 9 in the Appendix.

10. Readability error is a double factor derived from the difficulty in reading altitude and barometric scales with exact precision. It is called an operational error. For these tests, readability factors for all altitudes were-Altimeter scale 20 feet, and barometric scale 15 feet.
11. Backlash error arises because of lost motion in the gear transmission between the pressure scale and the height scale, and in the idler gear of the instrument. This error is 10 feet.
12. Zero-setting error is due to the shape of the tolerance curve with height. The tolerance at certain heights is different if a zero setting other than the standard 29.92" Hg. is used. The error shows a non-linear variation. The 15 feet shown for 5000 feet is used because no values are shown for lower altitudes.
13. Altimeter scale error is due to the physical properties and the construction of the aneroid and linkage. The diaphragm deflection is not linear, but will be different for the same given change of atmospheric pressure at different heights. An error factor of 30 feet is used, interpolated from values shown in the reference document. This error value includes hysteresis, after effect, drift, and recovery.
14. Static pressure error is 30 feet. The variables (Mach number and angle of attack) which affect the sensor and sensor position error in fixed-wing aircraft are of less significance in the helicopter than is the effect of rotor-induced turbulence. The 30 foot value is based upon an error of 25 feet per 100 knots IAS corrected to sea level conditions. The value assigned is consistent with the allowable tolerances for helicopter aircraft currently certificated for IFR.
15. Aircraft size error is identified in ICAO document no. 7672-AN/860. It is based upon the vertical airspace occupied by a fixed-wing aircraft with a wingspan of 120 feet in a 30 degree bank. The value stipulated is 75 feet. For the test series aircraft size allowance is based upon a disc diameter (rotor blades) of 80 feet and a 15 degree bank (20 feet) minus the 10 foot height allowance induced in altimeter settings. Thus the size-of-aircraft factor is 10 feet.

16. Atmospheric reference error is caused by variations in the atmospheric pressure following adjustments of the barometric dial or because of the use of two different altimeter settings by two aircraft flying in the same vicinity, as between two stations. ICAO document no. 7672-AN/860 assigned 200 feet as this error, but this was based on pressure variation of 4 mb per hour with distance between reporting stations of 130 NM, a geostrophic wind of 30 knots, and an assumption that the altimeter settings would not be over 1/2 hour old. In the present test, altimeter settings are assumed to be current and reporting stations are not more than 80 NM apart. The error is thus reduced to 100 feet.

The standard deviation of each of the errors identified as random errors was determined by dividing the error by a factor appropriate to the type of distribution. For those having a normal distribution, the factor is 3. For those with rectangular distribution, the factor is the square root of 3. For those having limit distribution, the factor is 1. These quotients are added statistically. Their sum, multiplied by 3, represents the maximum value for random errors for one helicopter, with a probability of 99.7%.

For two helicopters, the maximum random error for one helicopter is multiplied by the square root of 2.

For one helicopter and one fixed-wing aircraft, half the maximum random error for helicopters plus half of a similar value for fixed-wing aircraft are multiplied by the square root of 2.

The maximum random errors are added to the errors having no distribution and the resulting total errors represent the altitude which will provide safe vertical clearance for a helicopter; the altitude separation which will provide safe vertical distance between two helicopters; and the altitude separation which will provide safe vertical clearance between a helicopter and a fixed-wing aircraft. These total errors are shown in Figure 6.

SUMMATION OF ALTIMETER ERROR FACTORS FOR APPLICATION TO OBSTRUCTION CLEARANCE REQUIREMENTS--ROTARY WING AIRCRAFT--MEASURED IN FEET.

ERROR FACTOR	APPROACH	ENROUTE
Random Errors (99.7% Probability)	152	152
Zero Setting Error	15	15
Altimeter Scale Error	Corrected	30
Static Pressure Error	Corrected	30
Size-of-aircraft Factor	10	10
Atmospheric Reference Error	Corrected	100
TOTAL ERROR (FEET)	177	337

SUMMATION OF ALTIMETER ERROR FACTORS FOR APPLICATION TO SEPARATION REQUIREMENTS--BETWEEN TWO HELICOPTERS AND BETWEEN HELICOPTERS AND FIXED WING AIRCRAFT TRAFFIC--MEASURED IN FEET.

ERROR FACTOR	TWO HELI	HELI + FIXED WING	=	TOTAL H-FW
Random Errors (99.7% Prob.)	214	107 + 138	=	245
Zero-Setting Error	30	15 + 15	=	30
Altimeter Scale Error	60	30 + 100	=	130
Static Pressure Error	60	25 + 50	=	75
Size-of-aircraft Factor	10	10 + 75	=	85
Atmospheric Reference Error	100	50 + 50	=	100
TOTAL ERROR (FEET)	474	237 + 428	=	665

NOTES: Static pressure error for fixed-wing aircraft is based on an assumed 200 knot airspeed.

Random error values are computed by multiplying 1/2 the obstruction clearance value by the square root of 2. This provides the error contribution of each aircraft. See Appendix B of NACA TN 4127. If separation of two helicopters is desired, the value is doubled. If separation between helicopter and fixed-wing aircraft is desired the values for the two are added together. For computation of the random error factor see Appendix.

FIGURE 6. Altimeter Error Summation.

## LATERAL DEVIATION

Lateral displacement factors were analyzed by combining the flight technical errors with the ground station and airborne receiver errors using the root-sum-square method.

Radar data were assumed to be pure flight technical error due to the nearly perfect alignment of the radials flown and the exceptional accuracy of the Collins 51-RV-1 navigation receivers used. While some error is possible in this assumption, it is conservative, since the actual error should be smaller than the figure derived from radar tracks.

Ground station error was assumed to be not greater than a plus-or-minus 1.7 degrees at 95 percent probability. This assumption is drawn after a review of SAFI Bearing Error Reports.

Airborne receiver error was assumed to be 2.7 degrees at 95 percent probability. This is the current airline specification for air carrier equipment.

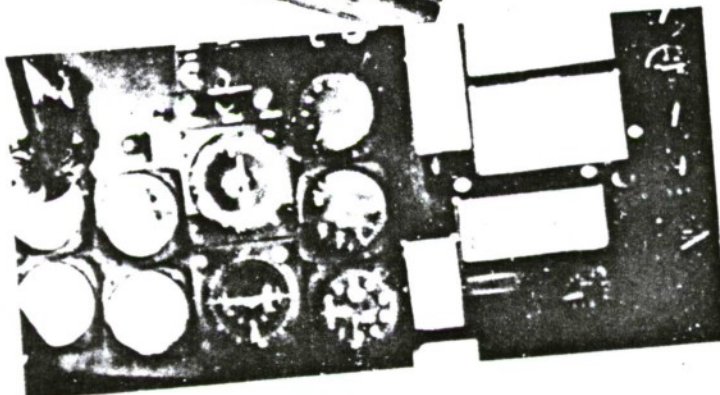
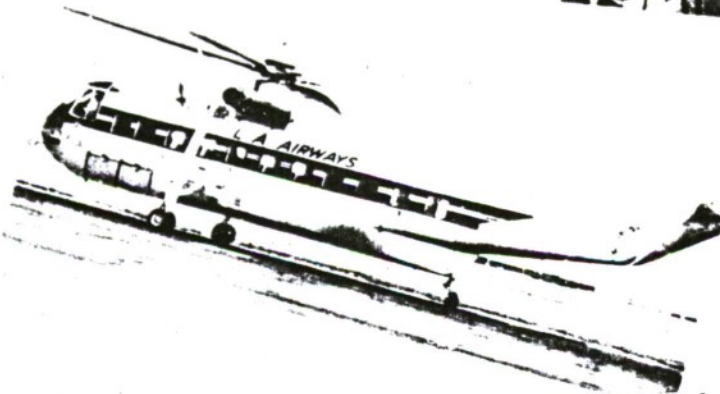
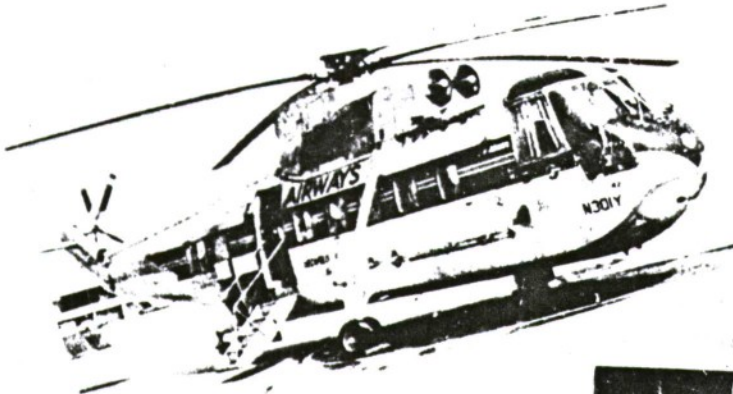
The result of combining these variables is shown in Figure 12, and compared to a 4 NM airway (2 NM each side of centerline). Lines connecting the 2-sigma (95%) and 3-sigma (99.7%) probability points indicate the feasibility of using these widths for stabilized air carrier helicopters by remaining well within the obstruction area boundaries.

In combining these variables the following methods were used:

Radar observations were measured in terms of nautical miles to the left or right of course centerline, and the angular error factors for ground station and VOR receivers were converted to nautical miles for each point where the tracks were measured.

While the total lateral error shown in Figure 12 is taken from actual tracks combined with other variables, the lines on Figure 13 were made from data grouped according to distance from the VOR station. For example, the 12-mile point includes all observations 12 miles from both the LAX and SNA VOR facilities.

Radar error tolerances are shown by circles on the plots in Figure 14. The circles indicate the areas within which radar error could allow the aircraft to be, considering the error to be the maximum allowable for the distance from the radar antenna to the data point. The method of measuring distances for these error values is shown on Figure 15.



## VI. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that the information developed during this project is sufficient to support the requirement for an enroute minimum obstruction clearance altitude (MOCA) of not less than 500 feet for IFR operations using stabilized rotary wing equipment.

It is further concluded that the 4-NM airway width is adequate for helicopter IFR operation when designated as the primary obstruction clearance area (95% probability) with the additional 1 NM secondary area (99.7% probability) on each side when the operation of stabilized air carrier helicopters is involved.

It is therefore recommended that the two conclusions above be combined to provide the following airway design criteria for specified routes assigned to air carriers using this type of equipment:

From the VOR to a point  $25\frac{1}{2}$  NM from the VOR the primary obstruction clearance area should be 4 NM wide; 2 NM on each side of the airway or route centerline. Obstruction clearance in this area should be not less than 500 feet. The secondary area is established 1 NM on each side of the primary area. Obstruction clearance should be not less than 500 feet at the inner edge, tapering to zero feet at the outer edge. See Figure 7.

Beyond a point  $25\frac{1}{2}$  NM from the VOR the primary area should be expanded. Since no data are available to the contrary, it is recommended that fixed-wing system accuracy be used beyond the  $25\frac{1}{2}$  NM distance to expand the airway gradually.

It is further recommended that the contents of this report be considered if any reduction in vertical separation is contemplated in the design of helicopter IFR airways.



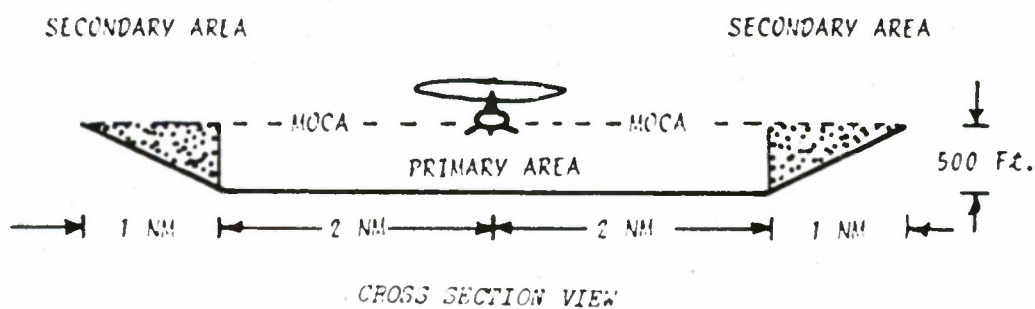
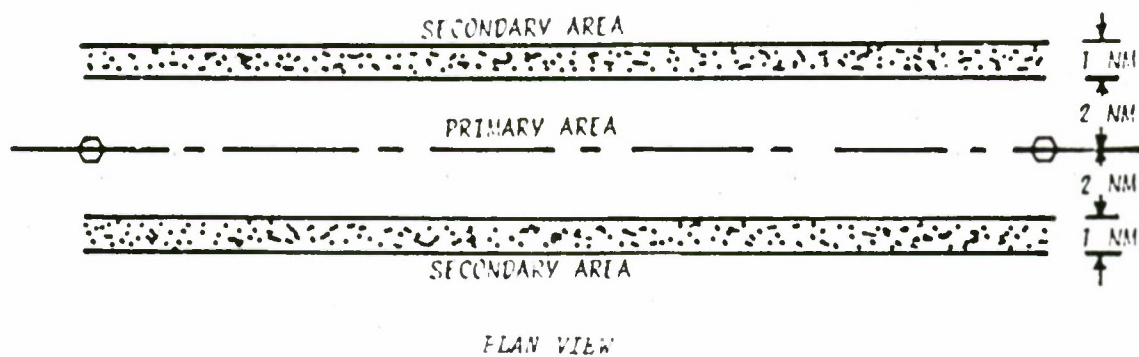
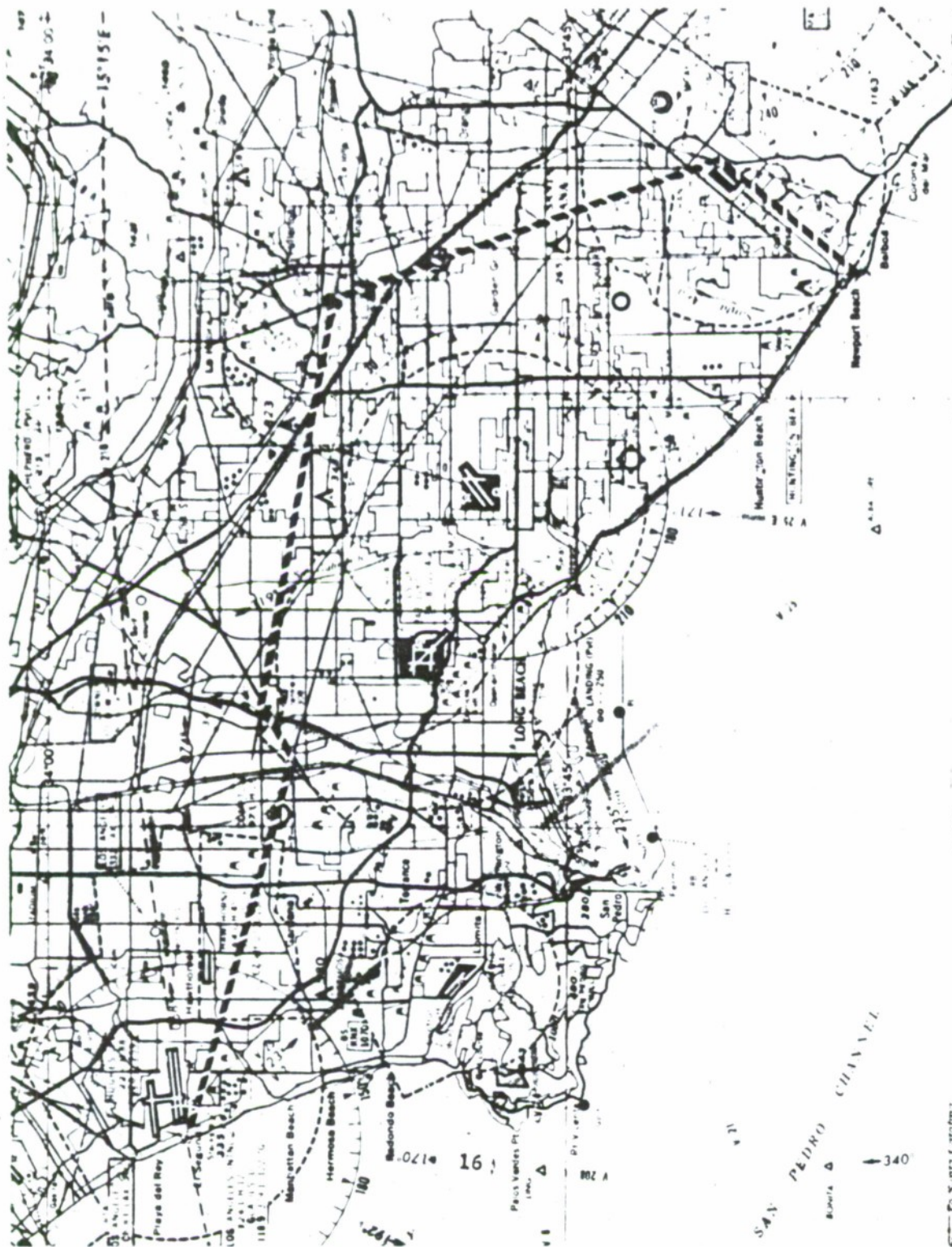


FIGURE 7. Proposed Helicopter Airway.

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San Pedro Channel

## VII APPENDIX

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STATISTICAL SUMMATION OF RANDOM ERRORS OF HELICOPTER AND FIXED-WING AIRCRAFT ALTIMETER SYSTEMS-NORMAL DISTRIBUTION FACTORS-IN FEET.

ERROR FACTOR	HELICOPTER	FIXED-WING (5000 ft)
Friction Error	100	30
Temperature Error	10	10
Instability Factor	32	32
Coordination Factor	25	25
Balance Error	20	20
Station Barometer Error	25	25
Manometer Error	10	10
Flight Technical Error	82	175

STATISTICAL SUMMATION OF RANDOM ERRORS OF HELICOPTER AND FIXED-WING AIRCRAFT ALTIMETER SYSTEMS-RECTANGULAR DISTRIBUTION FACTORS-IN FEET

Readability of Altitude Scale	20	20
Readability of Pressure Scale	15	15

STATISTICAL SUMMATION OF RANDOM ERRORS OF HELICOPTER AND FIXED-WING AIRCRAFT ALTIMETER SYSTEMS-LIMIT DISTRIBUTION FACTOR-IN FEET

Backlash	10	10
----------	----	----

NOTE: In computing root-sum-square values, a confidence factor of 3 is used in NORMALLY distributed factors; a factor of  $\sqrt{3}$  is used for RECTANGULARLY distributed factors; and the LIMIT distributed factor (backlash) is used directly.

FOR HELICOPTER AIRCRAFT:

$$\sigma = \sqrt{\left(\frac{100}{3}\right)^2 + \left(\frac{10}{3}\right)^2 + \left(\frac{32}{3}\right)^2 + \left(\frac{25}{3}\right)^2 + \left(\frac{20}{3}\right)^2 + \left(\frac{25}{3}\right)^2 + \left(\frac{30}{3}\right)^2 + \left(\frac{82}{3}\right)^2 + \left(\frac{20}{\sqrt{3}}\right)^2 + \left(\frac{15}{\sqrt{3}}\right)^2 + 10^2}$$

$$\sigma = 50.8$$

$$3\sigma = 152.4$$

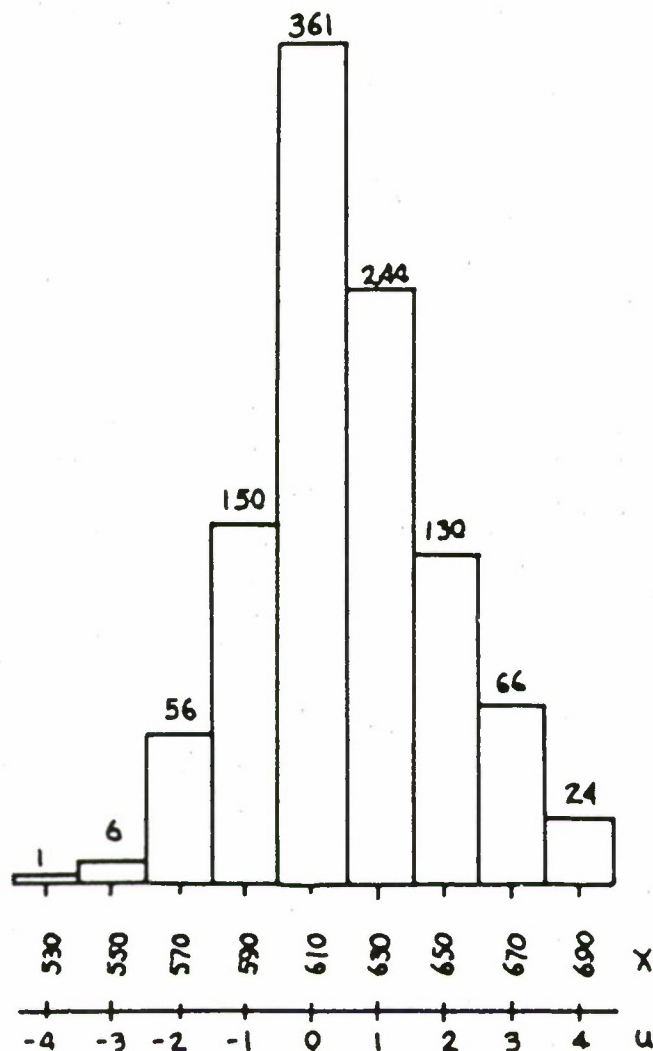
FOR FIXED-WING AIRCRAFT:

$$\sigma = \sqrt{\left(\frac{30}{3}\right)^2 + \left(\frac{10}{3}\right)^2 + \left(\frac{32}{3}\right)^2 + \left(\frac{25}{3}\right)^2 + \left(\frac{20}{3}\right)^2 + \left(\frac{25}{3}\right)^2 + \left(\frac{10}{3}\right)^2 + \left(\frac{30}{3}\right)^2 + \left(\frac{175}{3}\right)^2 + \left(\frac{20}{\sqrt{3}}\right)^2 + \left(\frac{15}{\sqrt{3}}\right)^2 + 10^2}$$

$$\sigma = 65.0$$

$$3\sigma = 195.1$$

FIGURE 8. Random Altimeter Errors.



$$\sigma = C \cdot \sqrt{\frac{n \cdot \sum u^2 f - (\sum u f)^2}{n(n-1)}}$$

$$\sigma = C \cdot \sqrt{\frac{1038(2166) - (518)^2}{1038(1037)}}$$

$$\sigma = 20 \cdot 1.36 = 27.2$$

$$3\sigma = 81.6 = \textcircled{82}$$

$$\bar{x} = \frac{C \cdot \sum u f}{n} + x_0$$

$$\bar{x} = \frac{20 \cdot 514}{1038} + 610$$

$$\bar{x} = 9.9 + 610 = 619.9$$

FIGURE 9. Flight Technical Error (VERTICAL)

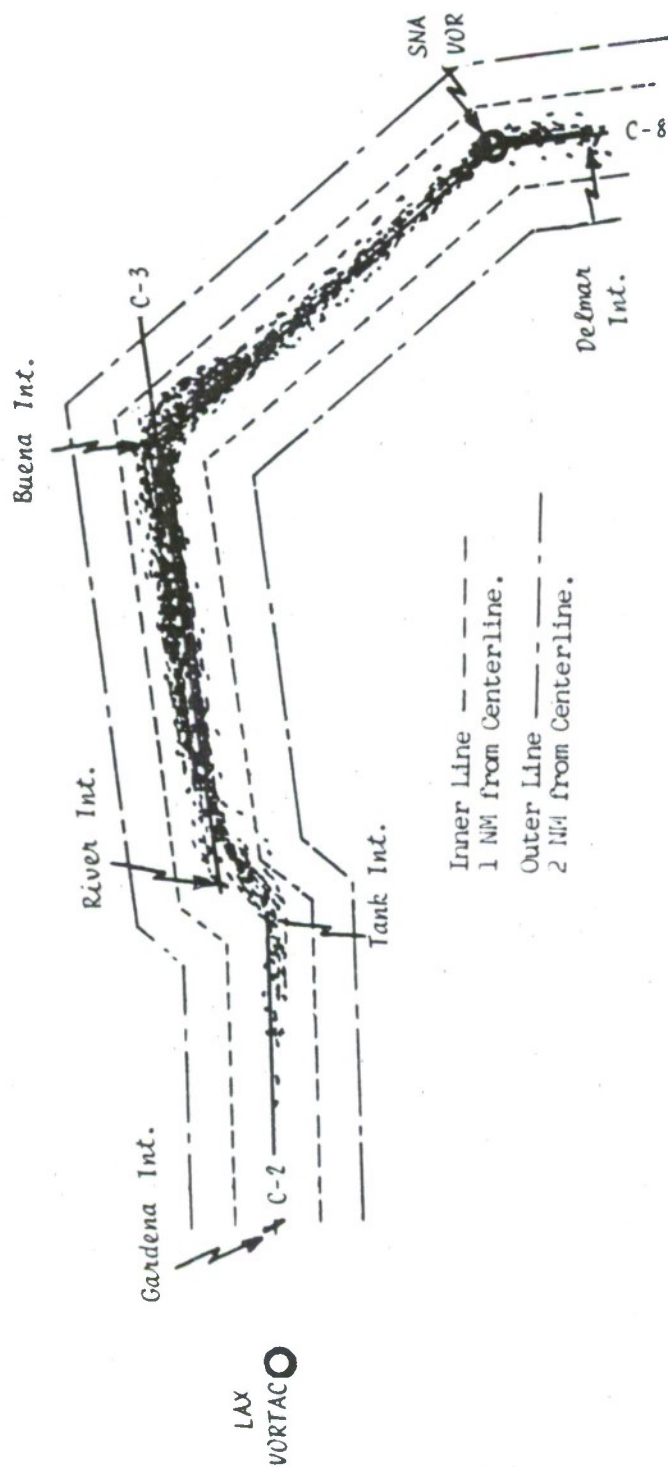


FIGURE 10. Radar Flight Tracks (COMPOSITE).

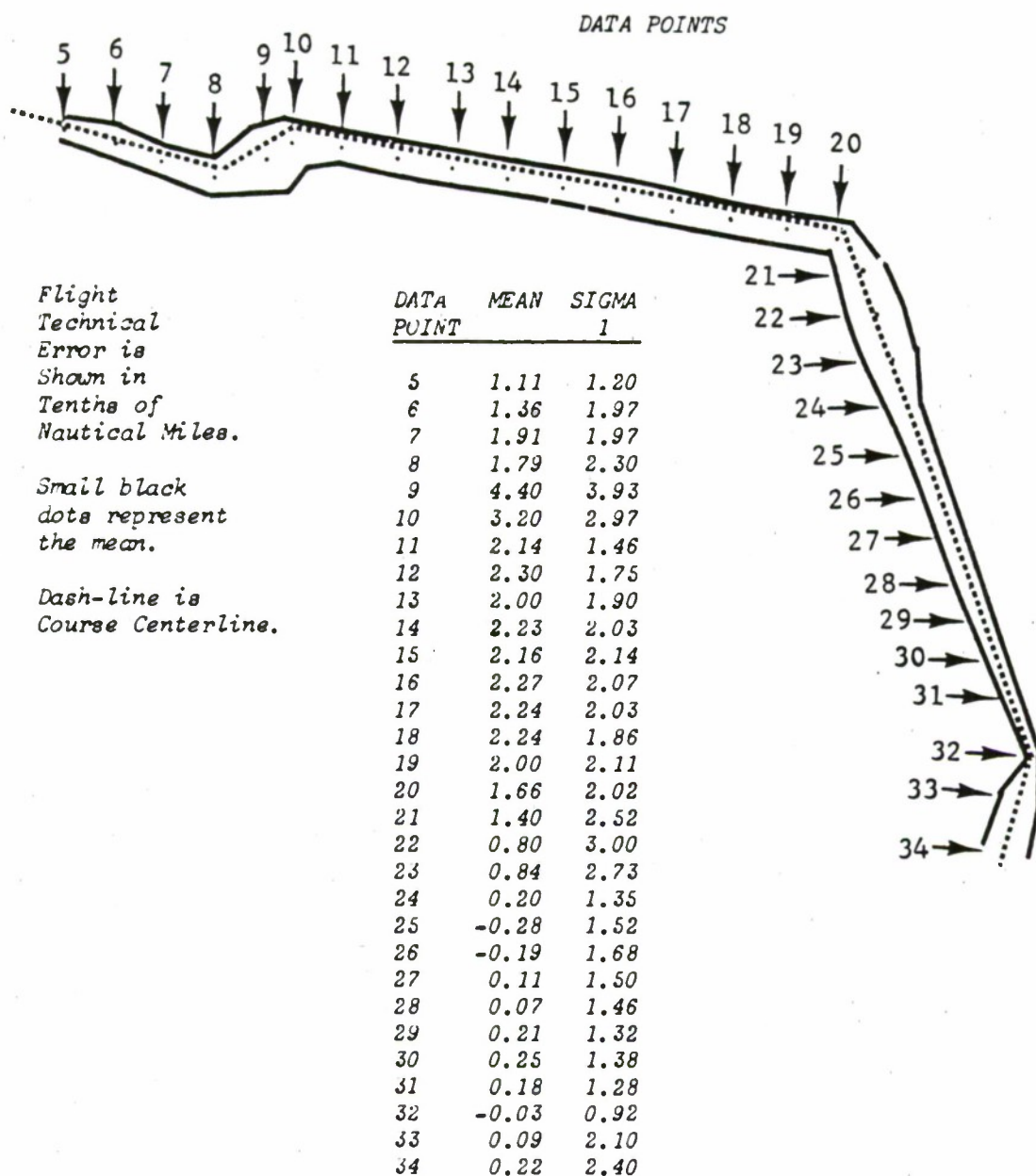


FIGURE 11. Flight Technical Error(LATEPAL)

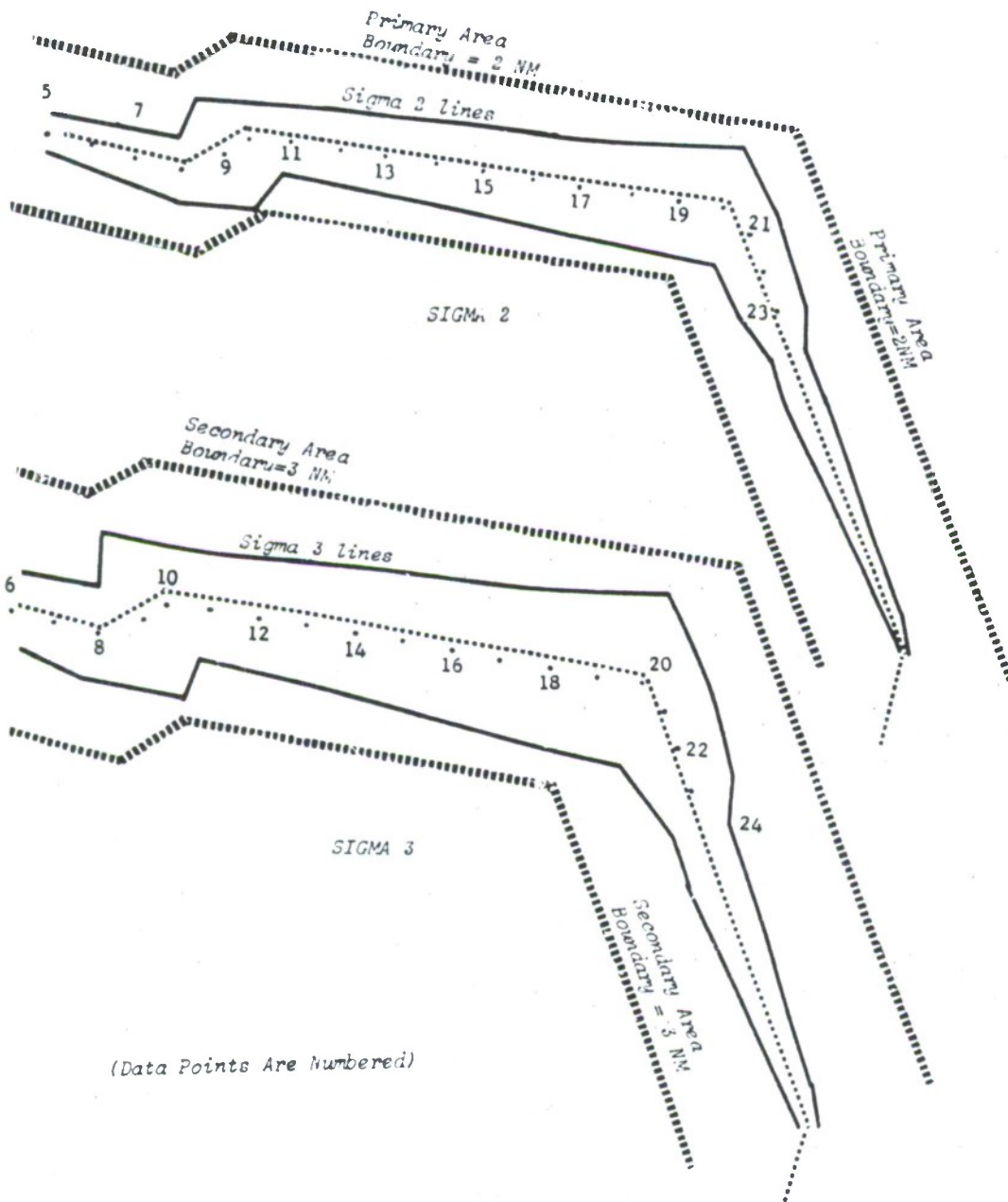


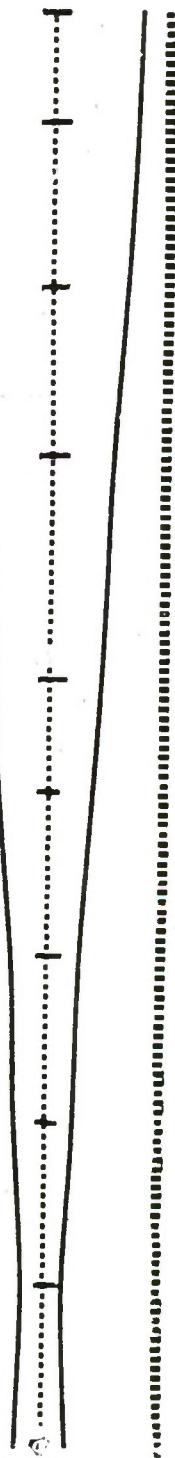
FIGURE 12. Total Lateral Error, Sigma 2 & 3.

(See Page 30 for distances from  
centerline)

# SIGMA 2

Primary Area Boundary = 2 NM

Sigma 2 lines



Nautical Miles from Facility



# SIGMA 3

Secondary Area Boundary = 3 NM

Sigma 3 lines

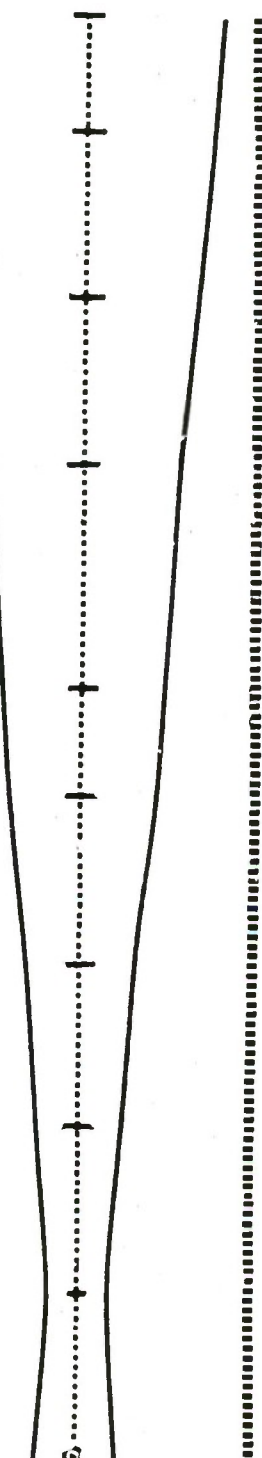


FIGURE 13. Lateral Errors Combined Statistically (ROOT-SUM-SQUARE).

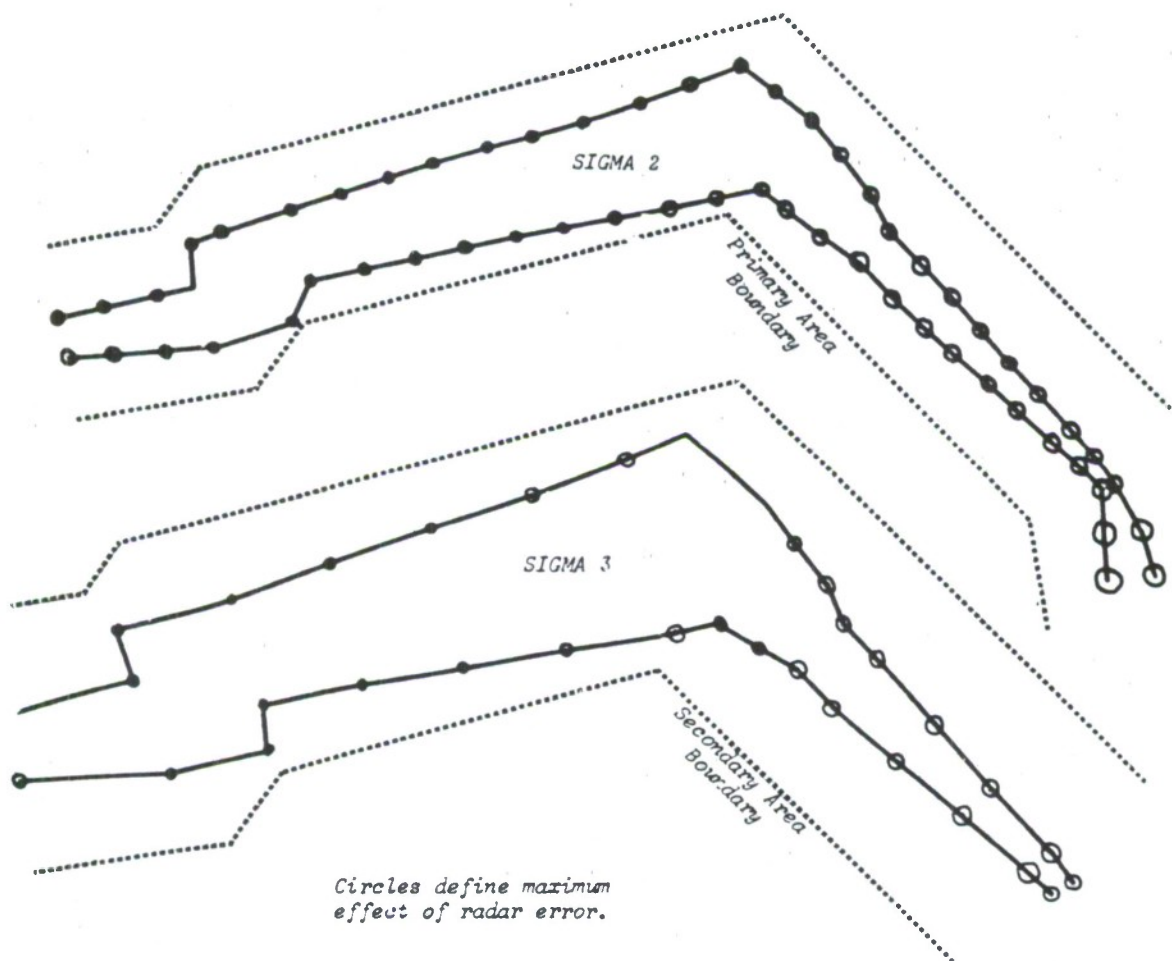


FIGURE 14. Radar Error Plots.

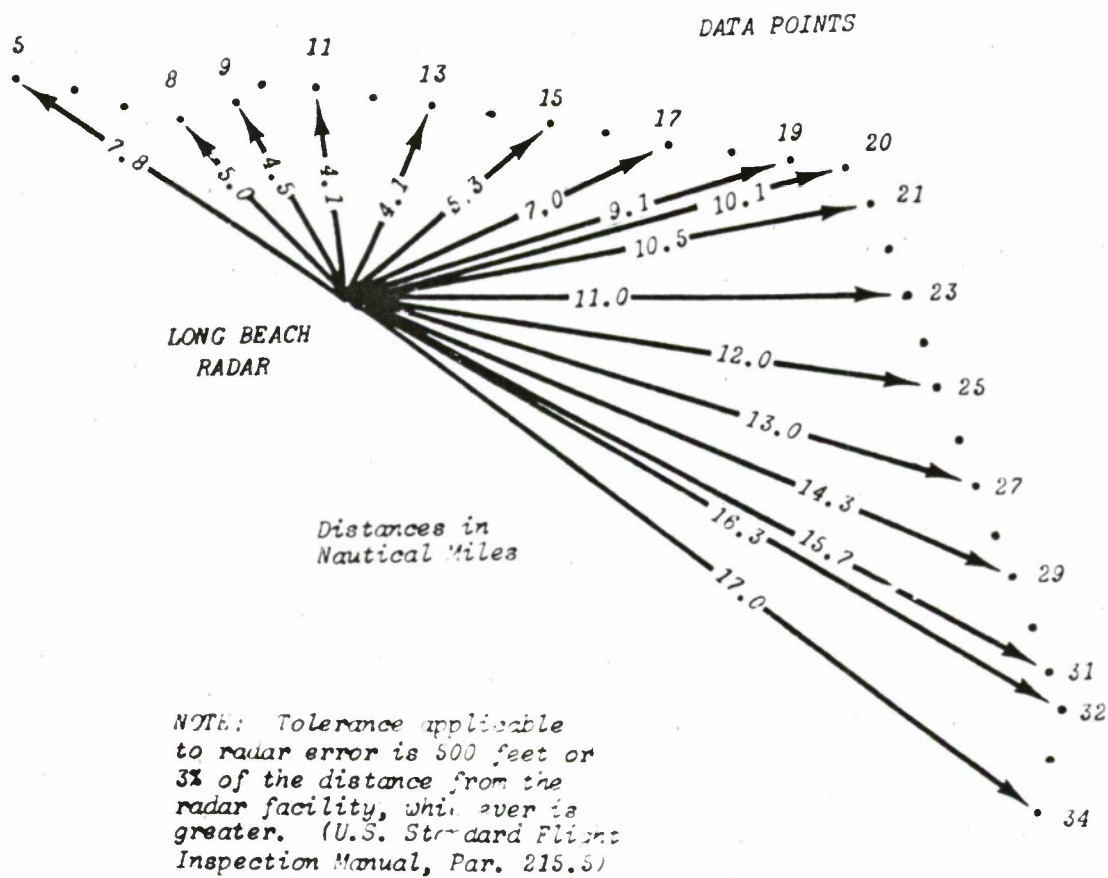


FIGURE 15. Radar Error Computation.

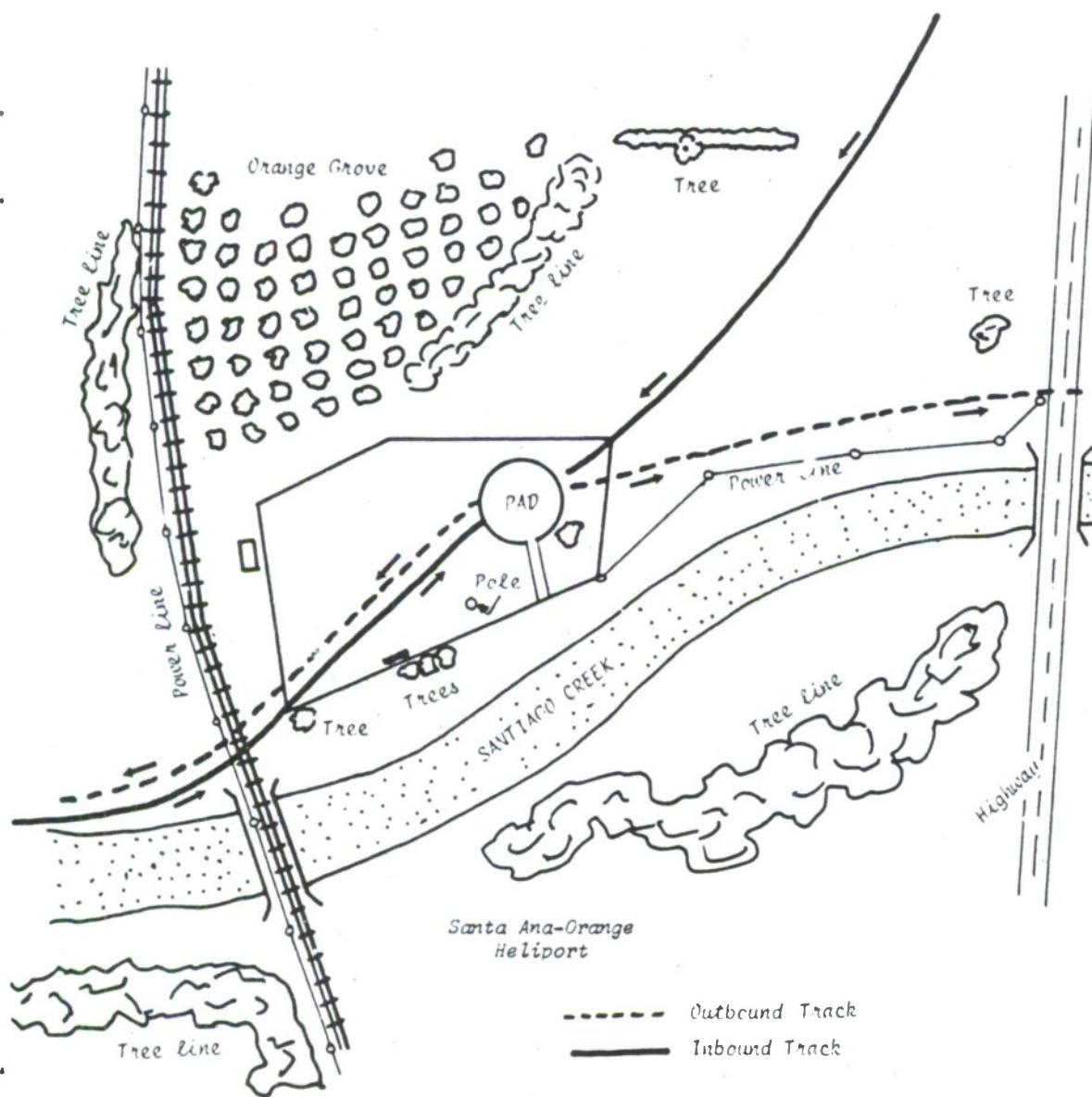


FIGURE 16. Typical Heliport.

## LAX - LAA AIRWAYS (IFR SIMULATED)

## RADAR OVERLAY RECORD DATA

Tabulation of Track Data at 1.0 NMI Intervals between GARDENA and DELMAR on C-2, C-3, and C-8 Airways.

Lateral Deviations in Tenths of NMI (+ = Right / - = Left) V = Vector

Run Number	1	2	3	4	5	6	7	8	9	10	11	12
Gardena $\Delta$	V	V	V	V	V	V	V	V	V	V	V	V
1												
2												
3												
4					0							
5					+2		+3	0				
6	+1				+4		+3	-2				
7	+2				+5		+3	-2				
8	+1		+6		+5		+3	-2		0		
(9	--		+9		--		--	-3	+3	-2		
TANK(												
$\Delta$ (10	--		+3		--		--	-4	+4	+2	0	+3
(												
11	+2		+2		+3	+3	+3	0	+1	+2	0	+2
12	+1		+2		+3	+3	+2	+3	+1	+3	-1	+2
13	+1		+3	+4	+3	+3	+2	+3	0	+2	-1	+3
14	+1	+2	+4	+4	+3	+3	+2	+3	0	+2	0	+2
15	0	+2	+5	+4	+2	+3	+2	+3	0	+2	+1	+2
16	+1	+2	+5	+4	+2	+3	+2	+3	0	+2	+1	+2
17	+2	+1	+5	+3	+2	+3	+2	+3	+1	+2	+1	+2
18	+2	+1	+4	+1	+3	+3	+2	+3	+1	+2	+1	+3
19	+2	0	+4	0	+3	+3	+2	+3	+1	+3	+1	+2
(20	+2	0	+3	0	+3	+3	+2	+2	+1	+3	+1	+2
(												
BEUNA(21	+2	+1	+1	+8	+4	+1	+6	-2	+1	0	+1	0
$\Delta$ (												
(22	+1	0	-1	+7	+3	+2	+4	-2	+1	0	0	+1
23	+1	+1	0	--	+2	+2	+2	-2	0	+1	0	+1
Disney 24	+1	+1	0	-4	+1	+1	+1	-2	0	+1	+1	+1
land 25	+1	+1	+1	-4			+2	-1	+1	+1		
26	+1	+1	+1	-4			+2	-2	+1	+1		
27	+1	+1	+1	-2			+2	+3	+1	+1		
28	+1	+1	+1	-1			+1	+2	+1	+1		
29	+1	+1	+1	+1			+1	+2	+1	+1		
30	0	+1	+1	+3			+1	+2	+1	0		
31	0	+1	0	+2			0	+2	0	0		
Santa(32	0	+1	0	+2			0	+2	0	0		
Ana (												
VOR (33	-2	0	0	+7			0	+3	-1	+1		
34	-1	+2	-2	+7			0	+3	-2	+3		
DELMAR 35	-1	+1	--	--			--	--	-2	+3		

Run No	13	14	15	16	17	18	19	20	21	22	23	24
GARDENA $\Delta$	V	V	V	V	V	V	V	V	V	V	V	V
1												
2												
3												
4			+2									
5			+1				+1		+3		0	
6			+2				+2		+5		0	
7			+3		+2		+2		+5		0	
8			+4		0		+2		+6		0	
(9X			+7		+4		+5		+7		+5	
(												
Tank (10X			+5		+5		+5		+7		+9	+1
$\Delta$ (												
11			+3		+3		+2		+4		+1	+5
12	+1	+2	+2		+2	+3	+1		+3	+5	0	+5
13	+2	+3	+1	+3	+1	+3	+1	+3	+2	+5	0	+5
14	+2	+3	+2	+3	+1	+4	+1	+4	+3	+5	0	+5
15	+2	+3	+2	+3	0	+3	+1	+5	+3	+5	0	+5
16	+2	+3	+2	+4	0	+4	+2	+6	+3	+5	0	+5
17	+2	+3	+2	+4	0	+3	+1	+6	+3	+5	0	+5
18	+2	+3	+2	+3	0	+3	+1	+7	+3	+5	0	+5
19	+1	+3	+2	+1	+1	+3	+1	+7	+3	+6	0	+5
(20	-1	+1	+3	-1	+1	+4	+1	+5	+3	+6	0	+4
(												
BUENA (21	-3	-1	+3	-2	+2	+4	+2	+5	+3	+6	0	+2
$\Delta$ (												
(22	-2	-1	+1	-4	0	+5	+1	+5	+4	--	+5	+2
23	-2	-1	-1	-3	-1	+6	0	--	+5	--	+6	+1
Disney- 24	--	--	-1	-2	-1	--	0	--	+2	--	+1	0
land 25			-2	-2	-1	+4					0	0
26			-1	-2	-1	+4					0	0
27			-1	-2	-1	+4					0	0
28			-1	-2	-1	+5					0	0
29			-2	-2	-1	+5					0	0
30			-2	-2	-2	+5					0	0
31			-2	-2	-1	+5					0	0
Santa 32			-2	-2	0	0					0	0
Ana (												
VOR (33			-2	-2	--	+2					0	0
34			--	--	--	+3					0	-1
DELMAR 35			--	--	--						+1	--
$\Delta$												

Run No.	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Gardena	V	V	V	V	V	V	V	V	V	V	V	V	V	V
1														
2														
3														
4														
5									0					
6				0		0			0					
7				0		0			0		+1			
(8				0		0			0		--			
(														
TANK (9				--		+9			--		--			
(														
(10				0		+1			--		--	+4		
11				0		+1			0		+4	+4		
12	0	-1	0	0		+1		+5	0		+4	+5		
13	0	-1	0	0		+3		+4	0	+6	-3	+5		
14	-1	-1	+1	0		+3	+5	+4	0	+6	-3	+5		
15	-1	-2	+1	0	0	+3	+4	+4	0	+5	-3	+5		+6
16	-2	-1	+1	0	0	+3	+4	+3	0	+5	-2	+5		+5
17	-2	-1	0	0	0	+2	+5	+4	0	+5	-1	+5		+5
18	-1	-1	0	0	0	+1	+6	+4	0	+4	-1	+5		+5
19	-1	-1	-1	0	0	0	+5	+4	0	+5	-1	+4	0	+5
(20	-2	-1	-1	0	0	0	+5	+4	0	+4	-1	+4	0	+3
(														
BUENA (21	-3	-1	-1	0	0	0	+4	+3	0	+2	0	+5	0	0
(														
(22	0	+1	0	-7	0	--	0	+5	--	+2	-7	+6	-4	0
23	+2	+4	0	-6	+1	--	0	+5	--	+2	--	+5	-4	0
Disney 24	0	0	--	--	V	--	--	+2	0	--	--	--	-2	0
land 25	+1	0	--	0	V	0	0	0	0	0	-1	-4	0	0
26	0	0	0	0	V	0	0	0	0	0	-1	-5	0	0
27	0	0	0	0	V	0	0	0	0	0	-1	-4	0	0
28	0	0	0	0	0	0	0	-1	0	0	-1	-4	0	0
29	0	0	0	0	0	0	0	0	0	0	-1	-2	0	0
30	0	0	0	0	0	0	0	0	0	0	-1	0	0	0
31	+1	0	+1	0	0	0	0	0	0	0	-1	-1	0	0
Santa (32	+1	0	-2	0	0	0	0	0	0	0	--	0	0	0
And (														
WCA (33	+1	0	-1	-1	--	0	0	+2	0	-5	--	--	0	0
34	0	0	0	-1	--	0	0	--	0	-5	--	--	0	0
DELMAR 35	0	0	+1	0	--	0	0	--	0	-5	--	--	+2	--
(														

DISTANCE FROM VOR	FTE $s^2$	STATION ERROR	AIRBORNE EQ. ERROR	RSS $\bar{X}$	LATERAL $s^2$	$s^3$
0	.0484	.0000		.008	.44	.66
3	.0196	.0026	.0053	.025	.33	.50
6	.0225	.0180	.0280	.011	.52	.79
9	.0196	.0246	.0485	.040	.61	.95
12	.0676	.0442	.865	.140	.89	1.34
14	.0676	.0595	.1175	.180	.99	1.48
18	.0324	.0950	.1950	.200	1.14	1.72
21	.0484	.1350	.2650	.220	1.34	2.01
24	.0441	.1770	.3440	.220	1.52	2.26
26	.0441	.2060	.4050	.170	1.62	2.43

Distances all in Nautical Miles  
FTE = Flight Technical Error

Lateral Deviation Table

END  
DATE  
FILMED  
8-4-69

**UNCLASSIFIED**

**UNCLASSIFIED**